

Computer vision technology in log volume inspection

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Abstract: Log volume inspection is very important in forestry research and paper making engineering. This paper proposed a novel approach based on computer vision technology to cope with log volume inspection. The needed hardware system was analyzed and the details of the inspection algorithms were given. A fuzzy entropy based on image enhancement algorithm was presented for enhancing the image of the cross-section of log. In many practical applications the cross-section is often partially invisible, and this is the major obstacle for correct inspection. To solve this problem, a robust Hausdorff distance method was proposed to recover the whole cross-section. Experiment results showed that this method was efficient.

Keywords: Log volume; Automatic inspection; Computer vision; Fuzzy entropy; Hausdorff distance

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Introduction

The measurement of log volume remains as a very important problem in forestry research, paper making industry and other related industries. Traditional approaches for this problem are based on manual measurement. For example, some approaches utilize calipers, some utilize ruler, and some directly utilize people's eyes to evaluate the volume via their experience. However, the traditional approaches are greatly affected by human factors, so the precision of measurement cannot be satisfied. In addition, the low efficiency of these approaches makes the work of measuring a bottleneck of procedure in production.

The use of computer vision to replace human vision is now widespread in industrial manufacture; there are many benefits in reducing fatigue and improving speed, consistency, and cost effectiveness. The computer vision system is referred to realizing visual function of human, i.e. realizing the recognition of three-dimensional objective world, by means of computer. To be precise, the system can understand the observed object's shape, size, distance away from the observational point, texture, motion feature (such as direction, velocity), and so on (Luan *et al.* 1997). This paper applies the computer vision technology into the automated inspection of log volume. It is well known that if we get the acreage of a log cross-section, the total volume of the log can be easily achieved by multiplying the acreage and its length. Here the acreage of a log is the average acreage of its two cross-sections (Luan *et al.* 1997). Therefore, this paper will focus on the inspection of the

cross-section of log based on a computer vision system.

The remainder of this paper is structured as follows. In section two, the inspection system is introduced. In section three, a novel fuzzy entropy approach to log cross-section image enhancement is developed. Then in section four, a robust version of Hausdorff distance is proposed to detect the occluded image problem. Experimental results are showed in section five. Finally, section six concludes this paper.

Inspection system

As Fig. 1 shows, the system consists of a personal computer, connected with an image board and a CCD camera. The image of log cross-sections is taken by CCD camera, then it is digitized as a 512×512 digital image by the image board, at last the digital image is processed by the computer.

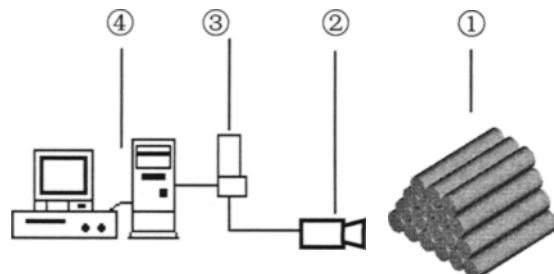


Fig. 1 Computer vision system

- 1. A pile of logs 2. CCD camera
- 3. Image board 4. Personal computer

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Enhancement based on fuzzy entropy

In many cases of log image processing, we have to deal with many ambiguous situations. Ambiguity caused by projecting a 3-D object into a 2-D image or digitizing analog pictures in digital images, and uncertainty related to boundaries and nonhomogeneous regions are very common. Fuzzy entropy theory is a very useful mathematical tool for handling the ambiguity or uncertainty.

The selection of membership is very important in the enhancement. In this paper, we choose the S-function as the membership function. It is defined as

$$\mu(x, a, b, c) = \begin{cases} 0, & x \leq a \\ \frac{(x-a)^2}{(b-a)(c-a)}, & a \leq x \leq b \\ 1 - \frac{(x-c)^2}{(c-b)(c-a)}, & b \leq x \leq c \\ 1, & c \leq x \end{cases} \quad (1)$$

where x is the variable in the intensity domain, and a , b and c are the parameters which determine the shape of S-function. We use this S-function to transform an image from the intensity domain into fuzzy domain. The parameters of the function can be determined by the maximum fuzzy entropy principle (Cheng *et. al.* 1999). The fuzzy entropy is defined as

$$H(A, N, \xi, \mu_A(x)) = \frac{-1}{\log N} \sum_{i=1}^N P_p(A_i) \log P_p(A_i) \quad (2)$$

where A is the fuzzy event, N is the number of partitions of A in the fuzzy domain, ξ is task-dependent parameter which may be equal partition or non-equal partition; $\mu_A(x)$ is the membership function. The term $P_p(A_i)$ is defined as

$$P_p(A_i) = \sum_{\mu_A(x) \in A_i} P(x) \quad (3)$$

where $P(x)$ is the probability of x in the intensity domain.

In this definition of fuzzy entropy, there are two settings that are task-dependent. One is the number of partitions N , and the other is the partition method ξ . In image processing, N can be set before the enhancement and the equal partition method can be applied. So the problem is to find a combination of (a, b, c) such that $H(A, a, b, c)$ has the maximum value. To solve this problem, a genetic algorithm can be used (Cheng *et al.* 1999). In the real application case, if the image of log cross-section is degraded, we can set the partition number N and use the genetic algorithm to maxi-

mum the fuzzy entropy, so the image can be enhanced.

Recovering the occluded section

In many case, due to the illumination problem, some log's cross-section could be partially occluded. So it is very hard to determine the whole area of the cross-section under this circumstance. In order to recover the whole area of the cross-section, we apply the image matching method which is based on a new Hausdorff distance (HD).

Given two finite point sets $A = \{a_1, a_2, \dots, a_p\}$ and $B = \{b_1, b_2, \dots, b_q\}$, the classical HD (Huttenlocher *et al.* 1993; Dubuisson *et al.* 1994) used to compute the distance between these two point sets is define as

$$H(A, B) = \max(h(A, B), h(B, A)) \quad (4)$$

where $h(A, B)$ and $h(B, A)$ denote the directed distance between the two sets A and B . They are defined by

$$h(A, B) = \max_{a \in A} \left\{ \min_{b \in B} \|a - b\| \right\} \quad (5)$$

$$h(B, A) = \max_{b \in B} \left\{ \min_{a \in A} \|a - b\| \right\}.$$

If we define $d_B(x) = \min_{b \in B} \|x - b\|$ and $d_A(x) = \min_{a \in A} \|x - a\|$, we have

$$H(A, B) = \max(\max_{a \in A} d_B(a), \max_{b \in B} d_A(b)) \quad (6)$$

Equation (6) implies that $H(A, B)$ can be obtained by computing $d_B(a)$ and $d_A(b)$ for all $a \in A$ and $b \in B$, respectively. We can get the value of $d_B(a)$ and $d_A(b)$ by using a distance transform algorithm (Borgefors, 1984 and 1986).

The HD is a true distance: it has the properties of identity, symmetry and triangle inequality (Paumard 1997).

Although the classical HD is simple and easy to compute, it has a serious weakness, i.e., the lack of robustness. In order to overcome this weakness, we propose a robust Hausdorff distance (RHD). The proposed RHD measure has taken into account the factors including outliers, occlusions and spurious features. Let us denote A the model image, and B the test image, then directed distance $h_{RHD}(A, B)$ is defined as

$$h_{RHD}(A, B) = \begin{cases} \left(\#(A)/\#(A')\right)^{\rho} \frac{1}{\#(A')} \sum_{a \in A'} d_B(a) & \text{if } \#(A') \neq 0 \\ M & \text{otherwise} \end{cases} \quad (7)$$

where M is a constant with large value; point set $A' = \{a | a \in A, d_B(a) \leq \beta\}$ where β is a threshold to eliminate outliers, it is selected experimentally. If $\#(A') = 0$, $h_{RHD}(A, B)$ is equal to M ; otherwise, its value depends on two terms, i.e., $(\#(A)/\#(A'))^{\rho}$ and

$\frac{1}{\#(A')} \sum_{a \in A'} d_B(a)$. The first term reflects the factor of $\#(A')$: the larger value of $\#(A')$ is, the smaller value of $h_{RHD}(A, B)$ will be. This term is useful to occlusions. ρ can be selected between 0 and 1. If ρ is selected to be 0, then the first term is equal to 1 and will not affect the value of $h_{RHD}(A, B)$. The second term is the average $d_B(a)$ of A' .

To define the directed distance $h_{RHD}(B, A)$, we should consider the problem of spurious features. For every point b in image B , we use $d_A(b)$ to form a new set B' where $B' = \{b | b \in B, d_A(b) \leq \beta\}$. In B' , use edge tracking method to remove the short edge segments that contain less than B_P points. B_P is usually selected to be 3. Then $h_{RHD}(B, A)$ is defined as

$$h_{RHD}(B, A) = \begin{cases} \left(\#(A)/\#(B')\right)^{\rho} \frac{1}{\#(B')} \sum_{a \in B} d_A(b) & \text{if } \#(B') \neq 0 \\ M & \text{otherwise} \end{cases} \quad (8)$$

Finally, $H_{RHD}(A, B)$ is defined as

$$H_{RHD}(A, B) = \max\{h_{RHD}(A, B), h_{RHD}(B, A)\} \quad (9)$$

This approach to object matching is simple and easy to implement. By appropriately choosing the value of β , outliers can be efficiently removed. Similarly, occlusions can be handled by the appropriate use of ρ . Therefore, this approach is insensitive to outliers and occlusions.

Therefore, it is obvious that even the cross-section of a log is partially occluded, we can recover the whole cross-section by using image matching method based on the RHD. The necessary thing is to construct several typical templates and get the edge of the image before the

matching process. When the correct match is obtained, the occluded cross-section is represented by the template.

Experiment results

An original image of logs is showed in Fig. 2. The image is degraded and it is difficult for further processing. We use fuzzy entropy based method to enhance the image. The image after enhancement is showed in Fig. 3. The parameter N in equation (2) is set to be 2. It is obvious that the quality of the image is enhanced after the enhancement processing. This image is more proper for the further processing.

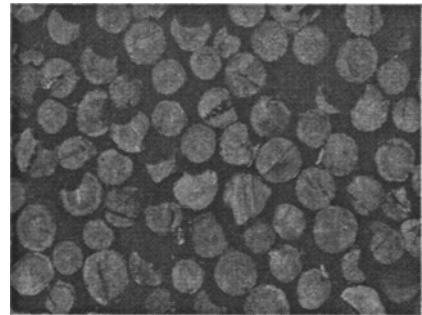


Fig. 2 An original image

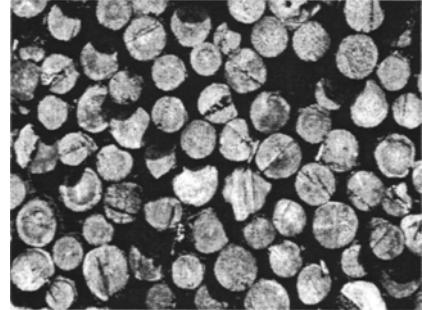


Fig. 3 The image after enhancement using fuzzy entropy method

From Fig. 3 we can easily find that due to the relative position of logs and the illumination problem, some log's cross-section are partially occluded. This will cause a big obstacle in volume inspection. The major problem we face is how to recover the occluded area so that the correct estimation of area can be achieved. Here we first find the edge of the cross-sections (Mero et al. 1975). The edge image of Fig. 3 is showed in Fig. 4. Based on this edge image, we can use the RHD to discover the matching between the image and the templates. When at a certain location, the image and the template is matched, but the

real area in the image is less than that of the template to some extent, we can make sure that the occlusion appears. Under this circumstance, the area in the image is overlaid by the template, and the calculation of the whole area at the matching location is based on the template. Further more, when we cannot find any edge point in a large area, we will put a template at the center of this empty area. The recovery of cross-section is showed in Fig.5.

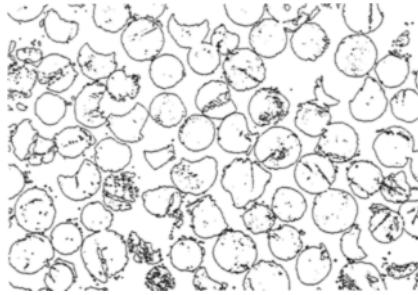


Fig. 4 The edge image of Fig. 3

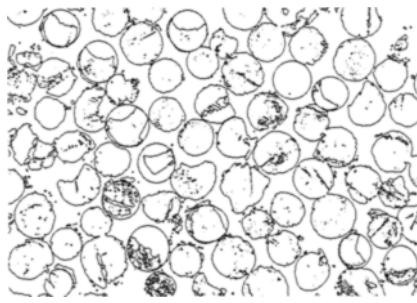


Fig. 5 The recovery of the cross-sections in Fig.4

Conclusions

A computer vision system to the inspection of log volume is developed in this paper. Some important methods have been introduced. This system can automated detect the cross-section based on image processing methods. In order to improve the effect of the image processing, we use fuzzy entropy method to enhance the degraded image and propose a robust Hausdorff distance to recover the partially occluded cross-section. Results have showed the feasibility of the proposed approaches. Future research will focus on improving the inspection precision of the system.

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